Administrative Rc'd Exh. 749

EVALUATION OF MIGRATION AND SURVIVAL OF JUVENILE FALL CHINOOK FOLLOWING TRANSPORTATION

TPE-00-1, OBJECTIVE 1F

2000 Draft Annual Report
December, 2000

Carl B. Schreck, Principal Investigator
Thomas P. Stahl, Project Leader
Mark D. Karnowski, Assistant Project Leader

Oregon Cooperative Fish and Wildlife Research Unit
Department of Fisheries and Wildlife
104 Nash Hall
Oregon State University
Corvallis, OR 97331-3803
(541)737-1961

EXECUTIVE SUMMARY

* Following release, fall chinook in the lower Columbia River migrated 136-143 kilometers downstream to the fixed monitoring station in 37.2-66.1 hours. Mean swimming velocity was 2.9 kph and ranged from 2.2 - 3.7 kph. There was no significant difference in migration speeds of barged and ROR fish in the only paired release.

* Movement of radio-tagged juvenile fall chinook in the lower estuary was influenced by the tide, with individuals moving downstream quickly on an outgoing tide and either moving slowly downstream or slightly upstream on an incoming tide.

* The portions of radio-tagged fish that successfully migrated to the estuary was examined; 55% of barged fish and 20% - 64% of ROR fish were observed at, or downstream of, the fixed monitoring station at river kilometer 89.4.

* None of radio-tagged fish were observed in colonies of piscivorous birds on Rice Island or East Sand Island.

* The lengths of the two types of radio-tagged fish were significantly different in the only paired release; barged fish were larger. Length was not related to migration speed for either barged or ROR types. The condition factor of the two types of radio-tagged fish was significantly different, the barged fish were higher.

* The ROR fish had significantly higher levels of gill Na^+/K^+ ATPase than barged fish.

* Plasma cortisol levels of barged and ROR fall chinook were not significantly different.

* Prevalence of bacterial kidney disease (BKD) was low, with at least 88% of the fish tested having no or low detectable levels of infection.

* The percent of fish selecting saltwater was not significantly different between barged and

ROR fish at 60 minutes or 120 minutes (all fish in saltwater) after the start of the experiment.

* An investigation performed on the difference between gastric and surgically implanted tags suggested that the surgical method may be the preferred method of implanting the tags.

* A study on antenna size suggested that a smaller antenna size decreased mortality from the tag and were heard more often – showing at least that the shorter size did not effect the ability to hear the fish in the study area.

TABLE OF CONTENTS

C29260

LIST OF TABLES

C29261

LIST OF FIGURES

C29262

C29263

OBJECTIVES

The goal of this study is to obtain information that will allow us to make recommendations concerning how the fish transportation program may be managed to minimize the severe loss of fish in the estuary. Specific objectives of the 2000 project were as followed:

1) Document post-transport behavior of juvenile passage delays of transported fall chinook salmon to inriver migrating fall chinook into and through the estuarine environment.

2) Determine and correlate fish condition to migration behavior through the estuary and saltwater interface to river condition and other indicators of estuarine productivity.

3) Establish the relationship between fish behavior in the estuarine and near-shore oceanic environment and the physiological indicators of fish quality. Examine the relationship between the developmental stage of the transported fall chinook to migration delays in the estuary and survival to ocean entry.

INTRODUCTION

The success of transportation is determined by the performance of the transported fish following release. Post-release performance of the fish is a function of fish quality at release, which is itself determined by both fish condition at collection and the effect of transportation. Fish condition at collection may be extremely important in affecting success of the program. Condition of fish when they reach the dam is extremely variable in terms of their general quality and health. There is not only variation over the course of the run, but also between individuals collected at any one time. We suspect that this variation in fish quality is reflected in the ability of juvenile salmonids to migrate down the lower Columbia River and successfully pass through the estuary.

Prior research of radio-tagged juvenile spring chinook salmon has found that 10-30% were taken by piscivorous birds in the Columbia River estuary (Schreck and Stahl, submitted). If this percentage is similar for fall chinook, than the total number of Columbia River smolts taken by birds near the mouth of the river could have a significant impact on salmonid populations. It is not known what factors determine the vulnerability of migrating juvenile salmonids to bird predators, although fish behavior in the estuary clearly has the potential to affect the likelihood of being eaten. For example, those individuals who swim higher in the water column or linger in areas containing many birds, may be more at risk. A number of factors relating to fish health and development (smoltification) have been shown to influence the behavior and survival of juvenile salmonids.

We postulate that the quality of migrants reaching the lower Columbia River (either by barge or in-river migration) relates to subsequent behavior and avoidance of predation. Fish quality may particularly relate to delays in seawater entry in the Columbia estuary. Such delays could result in more predation by increasing the amount of time the migrants spend in the freshwater lens, where the fish are exposed to large concentrations of birds and may be easier to catch due to the relatively shallow nature of the freshwater lens. Smoltification, disease, and stress status may all influence the amount of time a fish might be ○trapped○ in the freshwater lens. Prior research in the Columbia River (Schreck and Stahl, 1998) has suggested that the delay in seawater entry may be related to fish remaining in the surface layer of fresh water as long as possible, not to how much time is spent in the estuary. Although physiological condition influences behavior, the exact relationship between fish quality indices and behavior is not always intuitive. From the saltwater preference experiments, it has been demonstrated that seawater entry behavior of fish may not coincide with their physiological readiness. Once the linkages between fish quality and behavior are understood, the opportunity exists to manage the migration of juvenile salmonids through the Columbia Basin hydropower system to maximize downstream survival. Hence, how fish are ○delivered○ to the lower river could affect their ability or propensity to migrate; therefore, delivery systems (i.e., barging, passage of dams, or spill regulation) are tactics that may play various roles in affecting ocean entry success at various times throughout a run.

During the 2000 field season, information was collected concerning migration behavior of juvenile fall chinook in the Columbia River and estuarine environments. Increased understanding of smolt behavior in the estuary is needed to determine what may be done to minimize avian predation. Radio-tracking of different types of fish, barged and run-of-the-river (ROR), throughout the outmigration season was the primary objective. The observed behavior and survival of these fish was compared to hydrochemistry data taken in the estuary and physiological condition of other fish sampled at dams at the same time as fish were tagged. Finally, laboratory experiments were performed looking at how fish type (barged and ROR), smoltification levels, and BKD levels might affect the fish's preference for saltwater entry.

METHODS

1) Document post-transport behavior of juvenile passage delays of transported fall chinook to inriver migrating steelhead into and through the estuarine environment.

The migration behavior of yearling fall chinook in the lower Columbia River downstream of Bonneville Dam was documented using radiotelemetry. The migration of both barged and run-of-the-river (ROR) fish was examined. Radio transmitters were purchased from Advanced Telemetry Systems (ATS - Isanti, Minnesota) and operated on the 149 megahertz bandwidth. Standard transmitters were used, which weighed approximately 1.2 g in air and were designed to transmit continuously for a minimum of 7 days. Two Titley tags, which operated on the 148 megahertz bandwidth, were also purchased to see if these smaller tags (0.65 g in air) would work as well. To reduce the number of frequencies to be scanned during tracking, two tags were placed on each frequency and were distinguished by different beeping rates (approximately 40 or 60 beeps per minute). Before use, all tags were checked for proper functioning following a 24 h immersion in water.

Fish radio-tagged at Bonneville Dam or on the barge were released on two dates in mid to late June of 2000. Up to 22 fish of each type were tagged on each of the two dates over the 2000 outmigration. A detailed description of the dates, numbers, and characteristics of radio-tagged fish is contained in Table 1. On the first release, fish were not tagged on the barge due to the insufficient numbers of fall chinook in the holds and also because it was unknown if fish without an adipose clip could be used, a decision was made to not tag fish. All ROR fish used on the first release were adipose clipped hatchery fish, but on the second release, unclipped fish were used for both barged and ROR fish, so it is unknown if they were of hatchery or wild origin.

The barged fish were collected on fish transportation barges between John Day Dam and Bonneville Dam. Fish were netted from the holding tanks that contained smolts collected at the Lower Granite Dam Juvenile Fish Facility. Individuals were anesthetized in 50 mg/l tricane methanesulfonate (MS222) buffered with 100 mg/l $NaHCO_3$, after which the transmitter was surgically implanted into the body cavity using modified techniques from Moore et. al. (1990). The insertion point was sutured shut, antibiotics were applied, and Stress Coat® (Aquarium Pharmaceuticals, Inc.) was used to replace the loss of a naturally secreted coating. Following tagging, fish were placed in 125 liter live wells (3-4 fish/livewell) secured in the barge holds. After fish recovered (approximately 30 minutes), they were released from the livewells and returned to the barge holding tanks. An observer stayed on board after the barge passed Bonneville Dam to verify that all tags were transmitting and to record the release time and location.

Run-of-the-river yearling fall chinook to be radio-tagged were obtained at Bonneville Dam second powerhouse Juvenile Fish Facility (B2J) as part of the daily sample collected over a 24 hour period by Pacific States Marine Fisheries Commission (PSMFC) personnel for smolt monitoring purposes. Timing of these releases was designed to coincide with peak passage of Snake River juvenile salmonids past Bonneville Dam, so that we could obtain the highest proportion of Snake River fish for tagging (Figures 1A and 1B). On the dates of tagging, fall chinook were passing the dam, but the exact origin of individual implanted with a radiotag is unknown. After collection by PSMFC personnel, fish were placed in 125 liter livewells for subsequent tagging (approximately 2-5 h later). The tagging procedure was identical to that used for barged fish. At release, fish were placed back into the bypass system. In an effort to standardize the arrival time of barged and ROR migrants in the estuary (which might influence risk of predation from birds), releases at Bonneville Dam were made after the transport barge carrying the paired release group of radio-tagged fish had passed the B2J. The two groups were released six minutes apart in the paired release.

Due to high numbers of upper river mortalities during tagging in the first release (Figure 5), an experiment was performed to determine the differences in mortality from gastric and surgical tag implantation. The method for gastric (stomach) tagging was taken from Ward and Miller (1988). Fish were tagged until a total of five fish with each method was obtained. The numbers of mortalities that occurred immediately after tagging and 24 hours after was recorded. This study was used to decide which method should be used in the second release. Another study was also performed to determine if the size of the tag antenna would affect mortality from surgery and hearing efficiency of the tags.

Following release, radio-tagged individuals were monitored from an aircraft. Location data were collected daily for a period of 2-3 days starting on the first or second day following release, depending on weather conditions. The aircraft used for tracking was equipped with one ATS Challenger 2000 and one Lotek SRX_400 radio receiver; each was connected to antennas mounted on both wing struts. Flights were conducted at an altitude of 153 m with an air speed of approximately 160-177 kilometers per hour. Once a radio signal was heard, the plane circled until its precise location could be determined. The effective distance at which a tag could be detected ranged from approximately 0.4 to 1.6 kilometers. Due to the extreme width of the river in the estuary, the search pattern was a series of east/west transects spaced at 1.2 kilometer intervals. The transects were used from the mouth of the river up to river kilometer 48.3.

The progress of radio-tagged individuals was also recorded at a fixed monitoring station located upstream of river kilometer 89.4, near the community of Bunker Hill, Washington. This location is approximately 144 kilometers downstream of Bonneville Dam. In this area, the river is relatively narrow and the shipping channel abuts a series of cliffs on the Washington shoreline. Tracking data suggests that juvenile salmonids are often located in or near the shipping channel, and thus can be expected to pass near the Washington shore (and the monitoring station) at this site (Schreck et al., 1996, 1997). Two 6-element Yagi antennas were placed on a mast 3 m above the ground and approximately 31 m above river level. Antennas were pointed directly to the far side of the river and were each connected to a Lotek receiver. The same frequencies was entered into both receivers, but scanning was offset so that scan time for all frequencies was reduced. The monitoring station was staffed 24 hours a day during periods of tagged fish migration.

Detailed behavior of individual migrants in the estuary was examined. Either one or two 6 m Alumaweld boats (depending on available personnel), each equipped with one 4-element Yagi antenna and a Lotek receiver, were used to continuously monitor the behavior of individuals as they migrated down the estuary. Tracking began approximately one hour after the peak of high tide, usually in the morning. A boat would traverse the estuary monitoring both barged and ROR fish frequencies. When a signal was heard, the operators would stop scanning and only track that specific frequency. Once tracking began, the boat was kept as close to the fish as possible. At approximately 15 minute intervals, the location of the boat was located and recorded on a GPS (Global Positioning System; Garmin GPSMAP 230) unit. A fish was tracked until it moved into water too shallow for the boat, the signal was lost and could not be reacquired after set search limits, or other factors, such as weather, made continued tracking unsafe.

Water quality data were collected during tracking in order to determine the immediate environmental conditions associated with the fish. A YSI model 85 D.O./Salinity meter was used to measure water salinity and temperature. Readings were taken once per hour unless current, wave conditions, or possible loss of the fish being tracked precluded stopping for measurements. Data was collected at three depths for each location: the surface, half of the total depth, and near the bottom (taken from depth finders on the boats).

In order to get better estimates of mortality due to avian predators, one datalogging station was set up on Rice Island to monitor for radio-tags at the island's Caspian tern colony. Two stations were set up on East Sand Island; one station monitored the Caspian tern colony on the eastern side of the island and one station monitored the double-crested cormorant colony on the western side. These stations were placed to confirm and supplement the data collected by the aircraft over the islands. All stations consisted of a 6-element Yagi antenna mounted on a pole, 2 m above the ground. The antennas were plugged into a Lotek receiver, powered by a 12 volt deep cycle battery, located in a lockbox at the base of the pole. These stations were set up prior to arrival of fish in the estuary and data were downloaded after each release. Due to inconsistencies and random frequency interference, no data from these three stations was usable in 2000.

2) Determine and correlate fish condition to migration behavior through the estuary and saltwater interface to river condition and other indicators of estuarine productivity.

C29270

Yearling fall chinook were collected on one of the two releases in which radio-tagged groups were released (see Table 1). This allowed the health condition this cohort of radio-tagged fish to be documented and the differences in the response to transportation, collection, and handling to be measured. Health and smoltification indicators were compared to migration behavior (primarily migration speed) and survival of the corresponding radio-tagged groups in an effort to determine if these indicators are predictive of post-release performance.

Barged fish were obtained from the barge by pulling a lift net in the same compartments from which radio-tagged fish were taken from. ROR fall chinook were collected at Bonneville Dam, B2J, from PSMFC personnel when ROR radio-tagged fish were collected. The dates, numbers, and types of fish collected for these tests are given in Table 1.

For physiology sampling, fish were immediately killed with an overdose of anesthetic (200 mg/l MS222 buffered with 500 mg/l NaHCO3). The lengths, weights, presence of fin clips, and abnormalities (i.e., scale loss, puncture marks) were recorded for each fish. The caudal peduncle was severed and whole blood was collected using ammonium-heparinized capillary tubes. Blood was centrifuged, after which plasma was removed, and immediately frozen on dry ice. Plasma was later stored at -80° C. Gill filaments were collected, placed into a buffer solution, and frozen on dry ice (Zaugg, 1982). Whole kidneys were removed and frozen as well.

Plasma cortisol concentration was measured as an index of stress. Plasma cortisol is a widely accepted measure of the primary (neuroendocrine) response to stress (Mazeaud et al., 1977). Thawed plasma samples were assayed for cortisol using a radioimmunoassay (Foster and Dunn, 1974) as modified for use with salmonid plasma (Redding et al., 1984). Smoltification was estimated by measuring gill Na^{+}/K^{+} ATPase; which is an accepted index of this transformation (Hoar, 1988; Lysfjord and Staurnes, 1998). Gill samples were analyzed at the USGS-BRD Northwest Science Center, Columbia River Field Station (Cook, WA). Kidneys were analyzed for bacterial kidney disease (BKD) by the Oregon Department of Fish and Wildlife (526 Nash Hall, Corvallis, OR). Presence and severity of infection was measured using a modified

C29271

technique from Pascho et al. (1991).

3) Establish the relationship between fish behavior in the estuarine and near-shore oceanic environment and the physiological indicators of fish quality. Examine the relationship between the developmental stage of the transported steelhead to migration delays in the estuary and survival to ocean entry.

To establish a relationship between fish behavior in the estuarine and near-shore oceanic environment and the physiological indicators of fish quality, an experiment was designed. It examined the fish's preference for saltwater, comparing behavioral response to salinity with physiological indices. Results were related to the behavior of radio-tagged cohorts moving through the estuary and into saltwater.

A system for testing salinity preference was developed using a vertical salinity gradient. The experimental setup consisted of four 380 l rectangular fiberglass tanks (1.83 x 0.66 x 0.60 m) with acrylic windows in front to view the fish. Tanks were placed in a quite area and were visually isolated by black curtains. Saltwater was prepared (Instant Ocean™, 30 ppt) in separate tanks. At the start of a test, approximately 190 l of saltwater was pumped into the bottom of the observation tanks through perforated PVC pipe. This was done slowly, over approximately a 1 hour period, to establish a salinity gradient. The window of each test tank was marked to show the final dividing line between fresh and saltwater.

Barged fish were collected from the barge at Bonneville Dam, prior to entry into the Bonneville Navigation Lock. ROR fish were collected at B2J in the same manner as described in *Objective 1*. The dates, numbers, and types of fish collected for these tests are given in Table 1. Fish were placed in 125 liter livewells with air pumps and transported to Oregon State University§s Smith Farm Fish Physiology Laboratory. Twelve fish were placed in each of four observation tanks and allowed to acclimate for 51 hours. During acclimation, flow-through well water at 12.5° C was supplied to the tanks. Two tanks contained barged fish and two contained ROR fish. Following acclimation, the position of fish in the water column was observed and then the saltwater was introduced. The position of each fish was recorded every 10 minutes for 120 minutes, including the 60 minutes of saltwater introduction.

Statistical Analyses

Statistical analyses were performed on the following groups of fish:

1. "telemetry" fish - barged and ROR radio-tagged juvenile fall chinook (Objective 1)
2. "physiology" fish - barged, and ROR juvenile fall chinook collected for physiological sampling (Objective 2), and
3. saltwater preference fish – barged and ROR juvenile fall chinook collected for saltwater preference assessment (Objective 3)

Telemetry and physiology fish measures were compared both within fish types (i.e., barged and ROR fish) between releases (ROR fish only) and within the paired release between fish types. A single-factor ANOVA was used for most comparisons; this was a t-test because there were only two levels. In the cortisol comparison, only 13 individuals were compared (because the amount of plasma collected for the other fish was less than the amount necessary for the test) and a Kruskal-Wallis comparison of medians (nonparametric ranks) was used. For these tests, if a significant factor effect was found, differences between levels were assessed by Fisher's least significant difference (LSD) procedure at the 95% level. For comparisons of proportions with two levels (i.e., BKD presence in physiology), a Fisher's Exact Test was used.

Comparisons for the saltwater preference experiments were made using a Kruskal-Wallis test. These proportion data were arcsine transformed before analysis (though not presentation); the level of BKD infection within these experiments was compared with Fisher's Exact test.

RESULTS AND DISCUSSION

1) Document post-transport behavior of juvenile passage delays of transported steelhead to inriver migrating steelhead into and through the estuarine environment.

Following release, fall chinook in the lower Columbia River migrated 136-143 kilometers downstream to the monitoring station in 37.2-66.1 hours. The total distance individuals traveled over time can be seen in Figures 2A-2C. One of the barged fish moved upstream in Figure 2B, it is unknown why this occurred, but may be predator related. The speed in kilometers per hour (kph) which all individuals migrated from their release location near Bonneville Dam to the fixed monitoring station can be seen in Figure 3A. Mean swimming velocity (Figure 3B) was 2.9 kph and ranged from 2.2 - 3.7 kph. There was no significant difference in migration speeds of barged and ROR fall chinook in the only paired release ($p=0.8106$, ANOVA). The speed between the two releases of ROR fish was not significantly different ($p=0.2089$, ANOVA).

The length of the two types of radio-tagged fish was significantly different in the only paired release (Figure 4A; $p=0.0019$, ANOVA); the barged fish were larger. ROR fish were significantly larger on the second release than in the first ($p=0.0024$, ANOVA). The length of fish was not related to migration speed for either barged ($p=0.4179$, $R^2=0.0836$, linear regression) or ROR types ($p=0.6157$, $R^2=0.0161$). To determine if radio-tagged fish were biased from the general population due to tag:body weight constraints, fish sampled for physiological analysis were compared to radio-tagged fish; barged and ROR fish were not significantly different ($p=0.2494$; $p=0.4911$; respectively, ANOVA). The condition factor ($K = \text{weight (g)} / \text{length (mm)}^3 \times 10^5$) of the two types of radio-tagged fish was significantly different (Figure 4B; $p=0.0437$, ANOVA), with barged fish having a higher K. The K did not change between the two releases of ROR fish ($p=0.0854$, ANOVA). Again, to determine if radio-tagged fish were biased from the general population, fish sampled for physiological analysis were compared to radio-tagged fish; both barged and ROR fish were significantly different ($p=0.0366$; $p=0.0330$; respectively; ANOVA). When the K of the physiology fish was compared between types of fish there was not a significant difference ($p=0.3467$, ANOVA) unlike the radio-tagged fish. This comparison of radio-tagged and physiology fish suggested that fish used in radio-tagging were not longer but they did have a higher weight to length ratio.

The portions of fish that successfully migrated to the estuary was examined; 55% of the radio-tagged barged fish and 20% - 64% of ROR fish were observed at, or downstream of, the fixed monitoring station at river kilometer 89.4 (Figure 5). Radio-tagged fish that were never heard accounted for 40% of barged fish and 18% - 25% of ROR fish, which can also be seen in Figure 5. All tags were known to be functioning immediately before release, so these missing fish must be the result of : (1) fish that were dead on release and sank out of radio range, (2) fish that were taken by predators after release and whose remains were deposited out of radio range, (3) individuals that migrated successfully but went undetected. Regardless of the reason, certain individuals were never observed. It was assumed that all tags were inside fish, transmitting radio signals, and could be detected by the radio receivers. If this assumption is false, then the true sample size of observable radio-tagged fish is reduced and the relative proportion of fish reaching the estuary is higher than reported.

The high numbers of fish that were unheard and heard dead above the monitoring station in the first release (Figure 5) led into a small experiment on the survival rates of two tagging methods. The surgical implant method was used on steelhead in the 2000 field season (Schreck et. al., 2000) with good survival rates from surgery, yet when performed on smaller fall chinook salmon, results were not as positive, which can be seen in Figure 6. The gastric implant method was used in previous studies on spring chinook (Schreck et. al., 1996, 1997) and it was thought this may be a better tagging method. The experiment was performed with a small number of fish and was not meant to be a statistically valid study, but to give an idea on which method may be better. Personnel performing tagging had experience with both types of methods. A very high percentage of fish died immediately after the gastric implant (45%) and an additional 22% died after 24 h; these numbers were much higher than the surgical implanted tags which can be seen in Figure 7. From these data, it was decided to use the surgical implanted method for the second release of fish.

Another small study was performed pertaining to the antenna size of the tags used. The antennas were originally 30.5 cm in length, which were very long in comparison to the average length of fall chinook (11.2 cm). The antennas were cut to different size lengths to see if this had an affect on tagging survival and hearing efficiency. Seven fish were tagged with the original 30.5 cm length antenna, eight fish with a 22.9 cm length, and twelve with a 15.2 cm length. The results can be seen in Figure 8. The shortest length antenna had a higher percentage of fish recovering from surgery and more were heard migrating. It is possible the two factors are related, the fish with the longer antenna died after releasing, resulting in the fish not being heard. Even though more of the shorter length antennae were heard, this should not have been the case, since signal strength is determined by the antenna length. This experiment suggested at least the shorter length did not affect the ability to hear fish in the study area. It was decided to use an antenna length of 12.7 cm on the second release.

The two smaller Titley tags were tried this year to see if they would work as well as the standard ATS tags. Only one of the two tags was heard after release. This is a lower percentage than standard ATS tags but it is difficult to make any conclusions with only two tags. More studies would need to be performed to obtain meaningful results.

Of all radio-tagged fall chinook, none of barged or ROR fish were observed by aircraft or boats near colonies of piscivorous birds on Rice Island or East Sand Island and were considered mortalities. Having no mortality from the bird colonies from is very different from past studies (Schreck and Stahl, 1998; Schreck et al., submitted); this may be due to the small sample size of the fall chinook.

Migration routes of radio-tagged yearling fall chinook observed from the aircraft and by the boats (Figure 9A) appeared to fall into three general patterns based on two points of divergent routes. Fish made one ○decision○ slightly upriver from Rice Island; some stayed within the main shipping channel south of the island, and others followed the old shipping channel north of the island (○North Channel○). Those that were in the North Channel stayed in the northern part of the estuary (Washington side) until they reached the ocean (migration route 1). Those that remained in the shipping channel had another point of divergence near Tongue Point. Again, some stayed in the shipping channel all the way to the ocean (migration route 2); however, many crossed from the Oregon to the Washington side between Tongue Point and the Astoria Bridge and entered the ocean from the northern side of the estuary (migration route 3). These large-scale migration patterns are visible in Figure 9. Due to the small numbers of barged fish tracked, it is not known if there are any differences in large-scale migration patterns between barged (Figure 9B) and the ROR (Figure 9C) radio-tagged fish.

Generally, fish tracking began near Rice Island one hour after the peak of high tide (outgoing tide) when fish were moving relatively quickly. During slack tide (arbitrarily defined as one half hour before and one half hour after the peak of a tide) fish were still moving quickly and after the peak of low tide (incoming tide) the fish varied from moving downstream moderately quickly to moving slightly upstream. Figure 10A depicts these movement patterns for two fish tracked, a standardized time was used in this figure since fish were tracked on different days and the peak of low tide occurred at different times. Figure 10B shows the average speed and range of all tracked fish in the estuary during different tidal stages. There was not a significant difference between the speeds of the fish at these different stages ($p=0.3040$, Kruskal-Wallace test), possibly due to the large range during an incoming tide. The time it would take for a fish to migrate from river kilometer 48.3 to the ocean was estimated. A fish could travel approximately 6 h on an outgoing tide, move upstream slightly for 6 h on an incoming tide, again travel for 6 h on an outgoing tide, and so on until it reached the ocean; this would make the total estimated time to be 36.1 hours. This means it took approximately 3 tidal cycles (a cycle being defined as the peak of high tide to the peak of high tide) for a fish to move from the upper end of the estuary to the ocean.

A saltwater ○wedge○ existed in the estuary judged from the water quality data taken by boats as tracking occurred. Higher salinities existed near the bottom of the estuary, while lower salinity fresh water flowed over the saline water due to density gradients. Because only one fish was tracked into areas that had a stratified salinity profile, these measurements are not graphically presented.

C29278

2) Determine and correlate fish condition to migration behavior through the estuary and saltwater interface to river condition and other indicators of estuarine productivity.

Plasma cortisol levels of barged and ROR yearling fall chinook were compared for the paired release and there was no significant difference between the two types (Figure 11A; 0.5582, Kruskal-Wallace test). Gill Na^+/K^+ ATPase activity levels were compared and there was a significant difference between the two types (Figure 11B; p=0.0179, ANOVA); ROR fish had higher levels of ATPase. There was no significant relationship between ATPase and length, weight, or condition factor (p=0.7807, R^2=0.0044; p=0.7275, R^2=0.0069; p=0.5727, R^2=0.0180; respectively; linear regression). One interpretation of greater ATPase activity levels in ROR fish could be that they were more smolted. Another eventuality is that the two groups are not comprised of the same stocks of fish.

Prevalence of bacterial kidney disease was low, with at least 88% of the all the fish tested having no or low detectable levels of infection. When the proportion of fish with no infection was compared for the physiology fish, there was not a significant difference between types of fish (Figure 12; p=0.3034, Fisher's Exact Test); however, when comparing the fish used in the saltwater preference experiment, there was a significant difference between the two types (p=0.0354, Fisher's Exact Test).

3) Establish the relationship between fish behavior in the estuarine and near-shore oceanic environment and the physiological indicators of fish quality. Examine the relationship between the developmental stage of the transported steelhead to migration delays in the estuary and survival to ocean entry.

The saltwater preference experiment indicated no significant differences in the percent of fish in saltwater at 60 minutes (Figure 13A; $p=0.3173$, Kruskal-Wallace Test) or 120 minutes. No statistics were necessary at the 120 minute mark since all fish were in saltwater, showing a strong preference for saltwater in both types. There was a significant difference between the length of the types of fish ($p=0.0392$, ANOVA), but not in the K factor ($p=0.8045$). There was a difference between the proportion of fish with no BKD and the type of fish (Figure 15B; $p=0.0354$, Fisher's Exact test). Since nearly all fish of both types were in saltwater at 60 and 120 minutes, this suggests no relationship between length or BKD and saltwater preference.

The results of these experiments are very interesting when compared to gill ATPase levels. There was a significant difference in ATPase levels between the two types which could possibly be interpreted as a difference in the level of smoltification; however, this was not observed in their preference for saltwater.

C29280

CONCLUSION

There was no apparent difference in the migration speeds or patterns between barged and ROR fall chinook. Fall chinook exhibited similar migration patterns in the estuary as previously studied spring chinook salmon and steelhead (Schreck and Stahl, 1998; Schreck et. al., 2000). The migration speeds are also similar to the spring chinook and steelhead when examining releases during similar flow periods, suggesting a passive migration of all salmonids down the Columbia River.

There were significant differences in gill ATPase levels between types, one interpretation of this could be that there were differences in smoltification levels; however, experimentally, there were no differences in their preference for saltwater. This supports the hypothesis that high ATPase levels do not directly correspond to an increase in saltwater adaptability (Lysfjord and Staurnes, 1998) and that ATPase may not be a direct indicators of smoltification, at least on an individual level (Pirhonen and Forsman, 1998).

Some of the other experiments performed during the field season provided important tagging information for future years. An investigation performed on the difference between gastric and surgical implanted tags indicated that the surgical method may cause less mortality immediately after surgery and 24 hours after. A study on antenna size suggested that a smaller antenna size decreased mortality from tagging and were heard more often – showing at least that the shorter size did not affect the ability to hear the fish in the study area.

Timing of yearling fall chinook arrival in the estuary may be the most important factor affecting their survival. If smolt arrival in the estuary is timed correctly, a significant amount of mortality may be avoided. The fish should preferentially arrive at a daily or tidally beneficial time to avoid predation. Barging itself is probably not directly detrimental to the survival of fish; it is the secondary effects such as timing of barging that may be harmful to the outmigrants.

Another main factor that was hypothesized as an influence on the survival of fall chinook was

C29281

that the physiological condition would affect survivability. If a fish is not physiologically prepared to enter saltwater, it may behave in such a manner as to make it more vulnerable to avian predators. Better smolted fish prefer saltwater (Iwata, 1995; McInerney, 1964) and will therefore enter this deeper water more quickly, presumably avoiding predation. The data collected in this field season does not support the hypothesis that condition affects behavior and predation susceptibility. There were differences in length, condition factor, and gill ATPase, yet these differences did not effect the migration speed, migration patterns, mortality from piscivorous birds, or the preference for saltwater.

Further research and data analyses need to be completed before specific management recommendations can be made. Since only one paired release was made, data should be collected over several various flows during the same year and over multiple years to account for annual variability that characterizes the Columbia River system. A critical area that remains unexplored is at the mouth of the river; we have limited information concerning detailed migration behavior of juvenile fall chinook into saltwater. Increased understanding of smolt behavior at the freshwater/saltwater interface, which is miles long, may provide insight on what may be done to minimize rates of avian predation. Another area which should be investigated in more detail is how survival into saltwater ultimately affects returning spawner populations. An existing life-history model for salmonids should be developed and validated for the outmigrating juvenile stage. It can then be used to predict adult populations and effects of management decisions concerning the hydropower system and other areas of concern such as avian predators. Once the relationship between fish quality and behavior, as affected by river and estuary conditions, is understood, the opportunity exists to manage the migration of juvenile salmonids through the Columbia Basin hydropower system in such a way that their subsequent survival is maximized.

ACKNOWLEDGEMENTS

We would like to thank the U.S. Army Corps of Engineers, Walla Walla District for funding this research. Rebecca Kalamasz of the Corps provided guidance and support. Carol Seals, Shaun Clements, and other field-crew members provided valuable time and energy. Annie Qu, of the Oregon State University's Department of Statistics, provided helpful statistical consultation. We thank Robin Schrock and Jack Hotchkiss of the Columbia River Research Laboratory, U.S.G.S., Cook, Washington, for the analyses of gill ATPase activity, and Leslie Smith of the Oregon Department of Fish and Wildlife (526 Nash Hall, Corvallis, OR) for determination of *R. salmoninarum* rates.

C29283

LITERATURE CITED

Foster, L.B. and R.T. Dunn. 1974. Single-antibody technique for radioimmunoassay of cortisol in unextracted serum or plasma. Clinical Chemistry 20:365-368.

Hoar, W.S. 1988. The physiology of smolting salmonids. Pages 275-343 *in* Hoar, W.S. and D.J. Randall, editors. Fish Physiology, Volume XIB. Academic Press, San Diego, California.

Iwata, M. 1995. Downstream migratory behavior of salmonids and its relationship with cortisol and thyroid hormones: a review. Aquaculture 135:131-139.

Lysfjord G. and M. Staurnes. 1998. Gill Na^+-K^+-ATPase activity and hypoosmoregulatory ability of seaward migrating smolts of anadromous Atlantic salmon (Salmo salar), sea trout (Salmo trutta) and Arctic char (Salvelinus alpinus) in the Hals river, northern Norway. Aquaculture 168:279-288.

Mazeaud, M.M., F. Mazeaud, and E.M. Donaldson. 1977. Stress resulting from handling in fish: primary and secondary effects. Transactions of the American Fisheries Society 106:201-212.

McInerney, J.E. 1964. Salinity preference: an orientation mechanism in salmon migration. Journal of the Fisheries Research Board of Canada 21:995-1018.

Moore, A., Russell, I. C. & Potter, E. C. E. 1990. The effects of intraperitoneally implanted dummy acoustic transmitters on the behaviour and physiology of juvenile Atlantic salmon, Salmo salar L. Journal of Fish Biology 37:713-721.

Pascho, R.J., D.G. Elliott, and J.M. Streufert. 1991. Brood stock segregation of spring chinook salmon Oncorhynchus tshawytscha by use of the enzyme-linked immunosorbent assay (ELISA) and the fluorescent antibody technique (FAT) affects the prevalence and levels of Renibacterium salmoninarum infection in progeny. Diseases of Aquatic Organisms 12:25-40.

Pirhonen, J. and L. Forsman. 1998. Relationship between Na^+, K^+ - ATP-ase activity and migration behaviour of brown trout and sea trout (Salmo trutta L.) during the smolting period. Aquaculture 168:41-47

Redding, J.M., C.B. Schreck, E.K. Birks, and R.D. Ewing. 1984. Cortisol and its effects on plasma thyroid hormones and electrolyte concentrations during seawater acclimation in yearling coho salmon, Oncorhynchus kisutch. General and Comparative Endocrinology 56:146-155.

Schreck, C.B., L.E. Davis, and C. Seals. 1996. Evaluation of procedures for collection, bypass, and transportation of outmigrating salmonids, Objective 1: Migratory behavior and survival of yearling spring chinook salmon in the lower Columbia River and estuary. Draft Annual Report 1996, Project MPE-96-10. U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, Washington.

Schreck, C.B., L.E. Davis, and C. Seals. 1997. Evaluation of migration and survival of juvenile salmonids following transportation. Draft Annual Report 1997, Project MPE-95-3. U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, Washington.

Schreck, C.B. and T.P. Stahl. 1998. Evaluation of migration and survival of juvenile salmonids following transportation. Draft Annual Report 1998, Project MPE-W-97-4. U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, Washington.

Schreck, C.B., T.P. Stahl, and L.E. Davis. Submitted. Survival of transported and run-of-the-river outmigrating juvenile salmonids in the lower Columbia River system. Transactions of the American Fisheries Society.

Schreck, C.B., T.P. Stahl, M.D. Karnowski and S. Clements. 2000. Evaluation of migration and survival of juvenile salmonids following transportation. Draft Annual Report 2000, Project TPE-00-1, Objective 2C. U.S. Army Corps of Engineers, Walla Walla District, Walla Walla, Washington.

Ward, D.L. and L.M. Miller. 1989. Using radiotelemetry in fisheries investigations. Oregon Department of Fish and Wildlife (Fish Division) Information Reports No. 88-7.

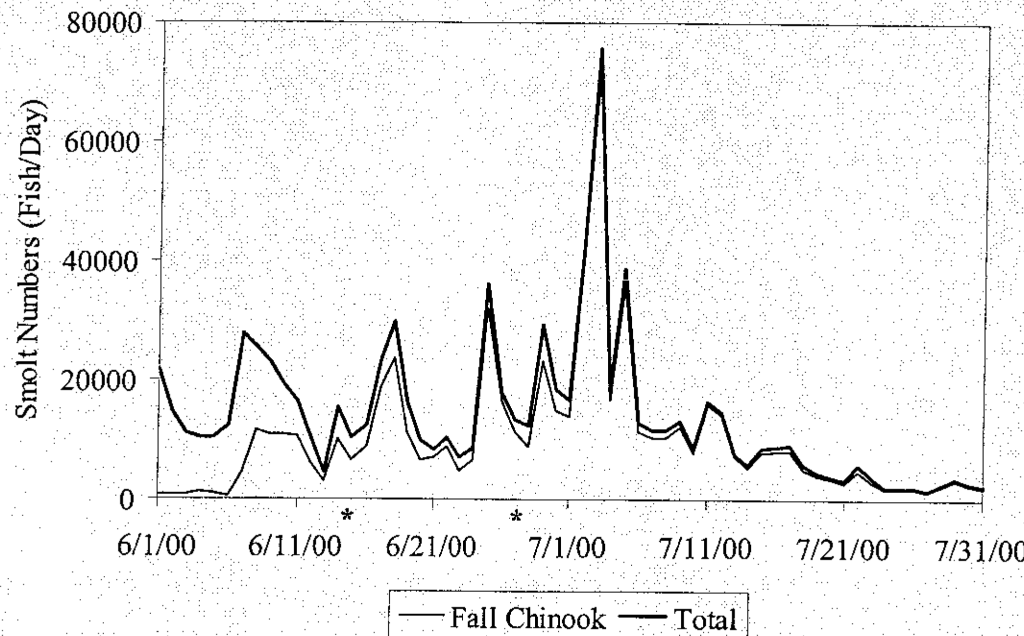
Zaugg, W.S. 1982. A simplified preparation for adenosine triphosphatase determination in gill tissue. Canadian Journal of Fisheries and Aquatic Sciences 39:215-217.

Table 1. Summary of fish used during the 2000 field season. Numbers, length, and weight of fish used for radio-tracking, physiological sampling, and saltwater preference (SWP) experiments are given for each release of fish. Mean and range (in parenthesis) are given for lengths and weights.

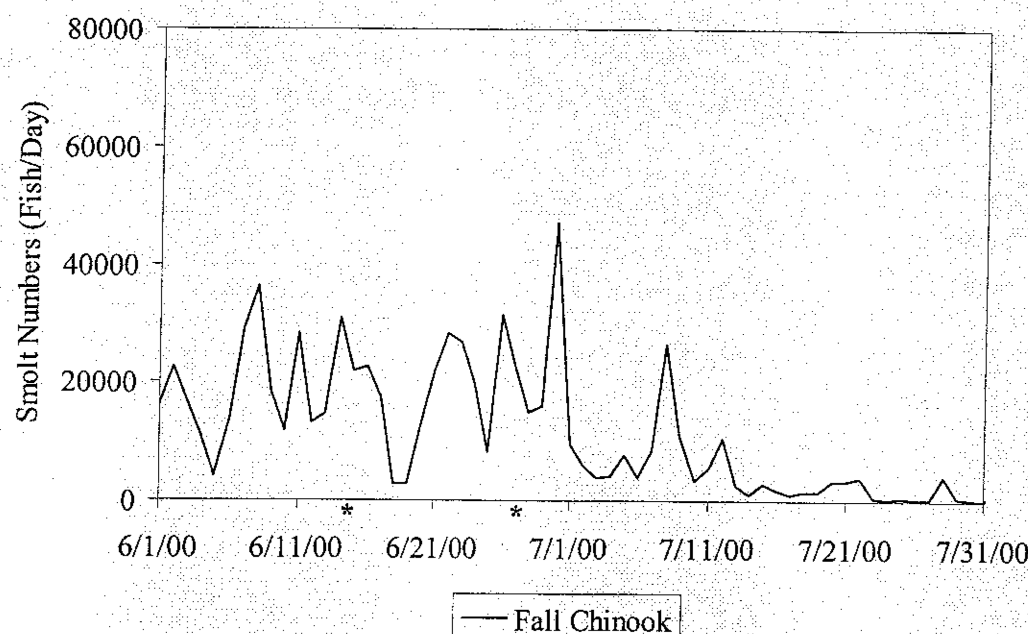
Sampling Type	Fish Type	Sampling Date		
		6/14/00	6/25/00	6/27/00
# of Tagged Fish Released	Barged			20
	ROR	20		22
# of Physiology Fish	Barged			10
	ROR			10
# of SWP Fish	Barged		23	
	ROR		24	
Length of Tagged Fish Released (mm)	Barged			124 (110-140)
	ROR	110 (104-126)		116 (105-135)
Length of Physiology Fish (mm)	Barged			120 (105-135)
	ROR			111 (103-116)
Length of SWP Fish (mm)	Barged		103 (90-117)	
	ROR		109 (89-135)	
Weight of Tagged Fish Released (g)	Barged			20.8 (15.0-28.8)
	ROR	13.5 (11.4-20.7)		16.4 (12.9-26.3)
Weight of Physiology Fish (g)	Barged			17.7 (10.8-26.3)
	ROR			13.4 (11.4-15.7)
Weight of SWP Fish (g)	Barged		11.1 (7.3-15.5)	
	ROR		13.3 (7.6-28.3)	

Figure 1. Daily collections of (A) juvenile salmonids at Lower Granite Dam and (B) fall chinook at Bonneville Dam. Dates on which barged and ROR fall chinook were collected for radio-tagging are indicated by asterisks (*). Smolt numbers were obtained on the internet at http://www.cqs.washington.edu/dart/pass_com.html, courtesy of the Fish Passage Center.

. Lower Granite Dam



B. Bonneville Dam



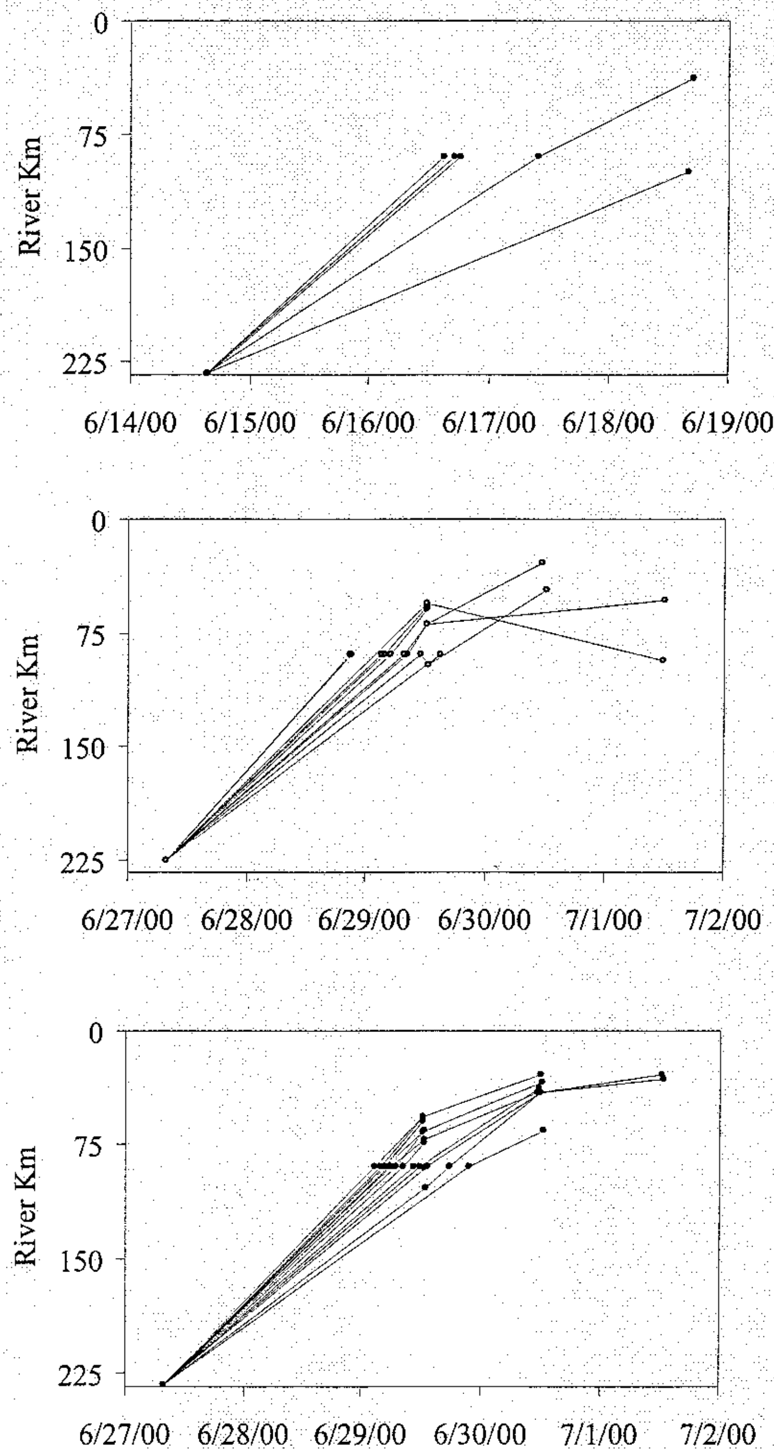
C29287

Figure 2. The distance traveled downstream over time for (A) ROR fall chinook during the 6/14/00 release, (B) barged fish in the 6/27/00 release, and (C) ROR fish in the 6/27/00 release. The distance was calculated from fixed monitoring station, boat, and plane data points.

A. ROR

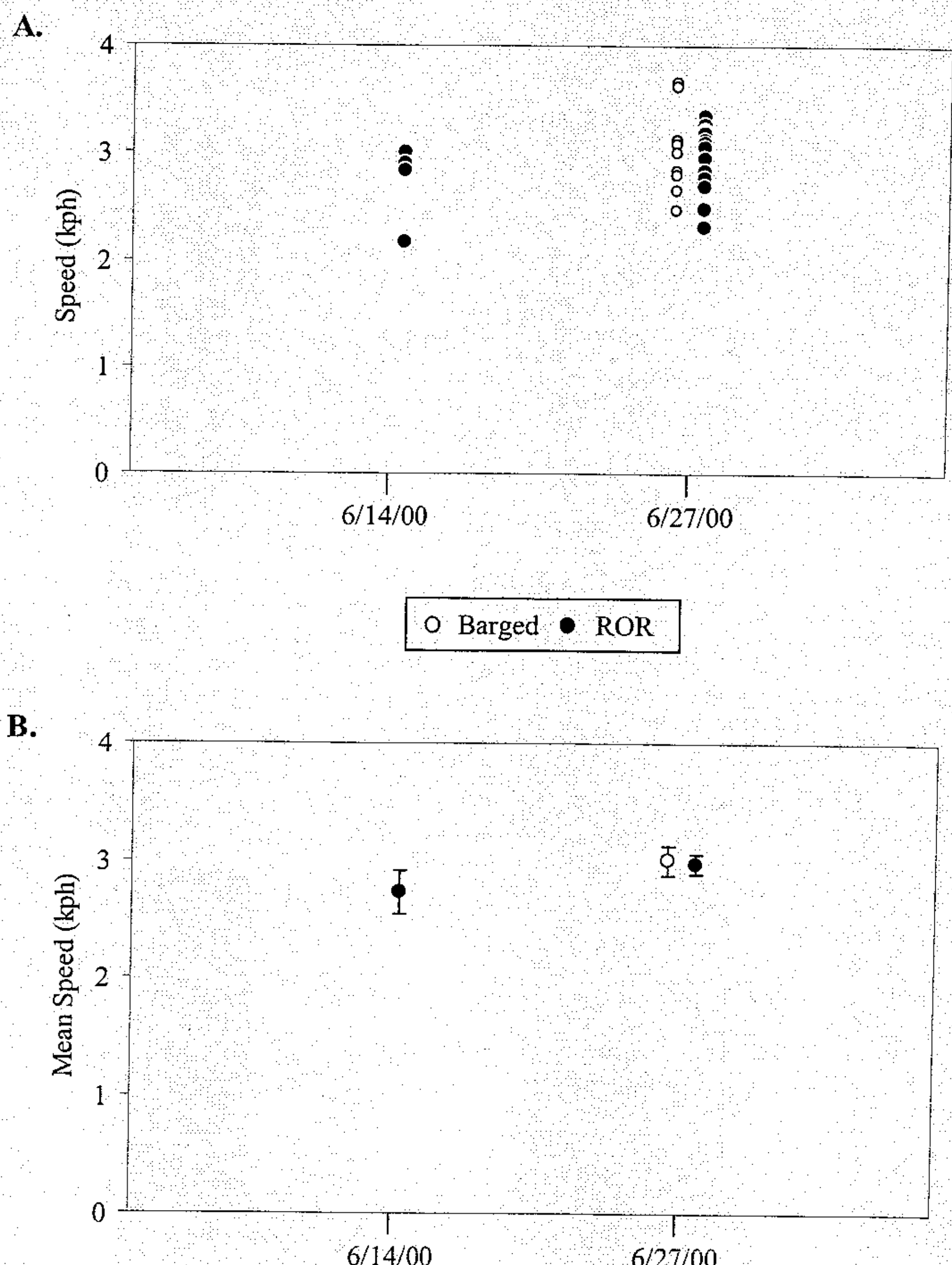
B. Barged

C. ROR



C29288

Figure 3. (A) Migration speed in kilometers per hour (kph) of all radio-tagged fish and (B) mean speed for each release of barged and ROR fall chinook measured from the release site to the fixed monitoring station near the upstream end of the Columbia River Estuary. Significant differences are described in the *Results* section.



C29289

Figure 4. (A) Mean length and (B) condition factor of the radio-tagged barged and ROR fall chinook. Significant differences between types within a date are indicated by asterisks (*).

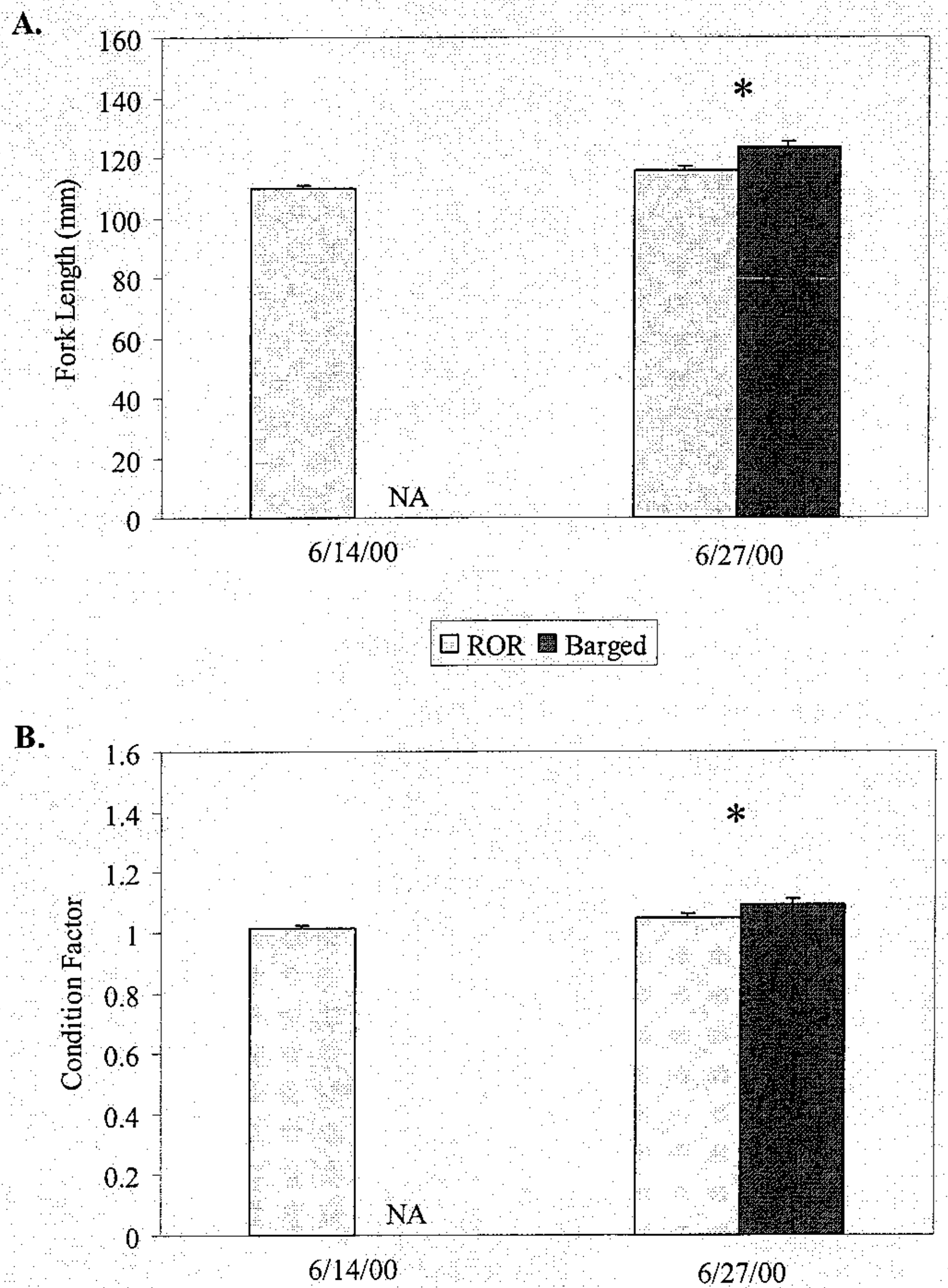
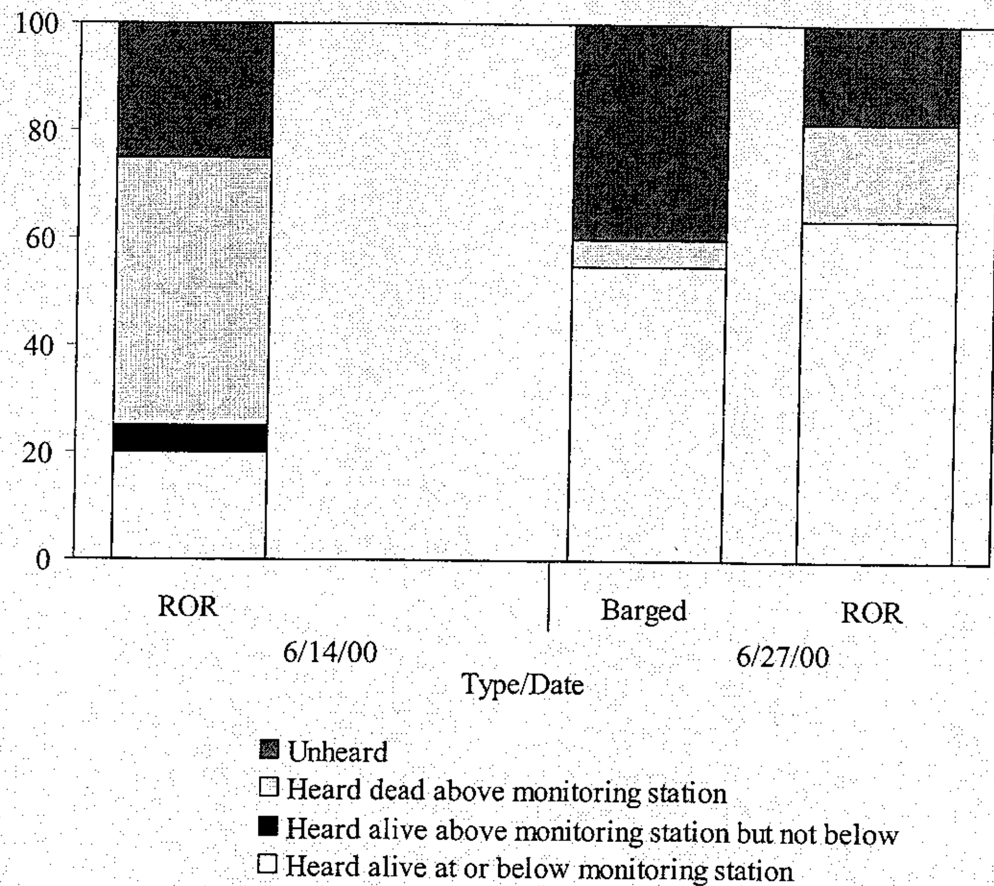
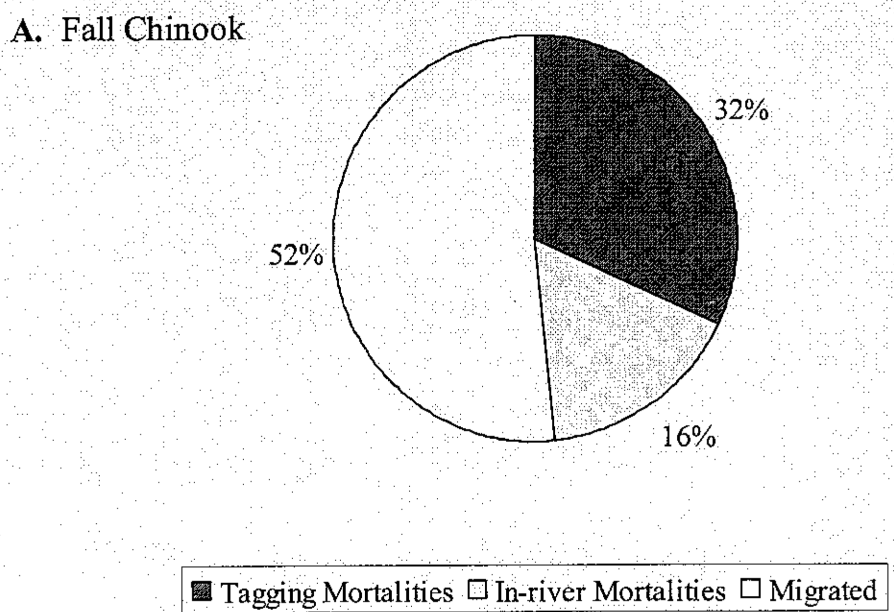


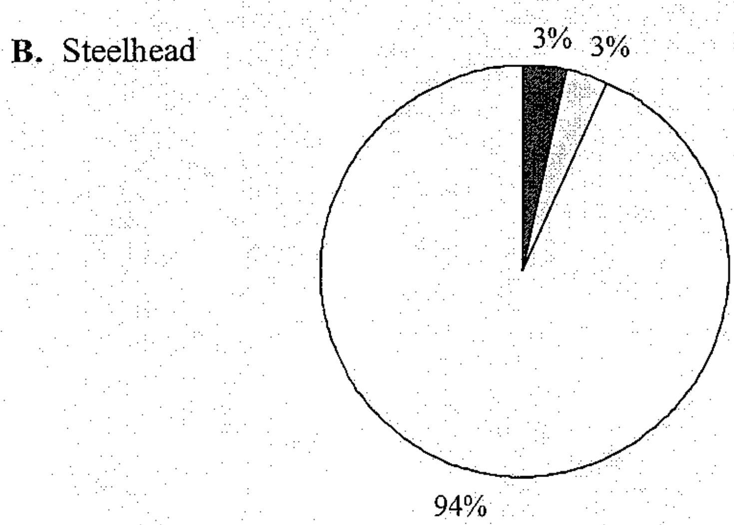
Figure 5. The percentage of where radio-tagged fish were heard.



C29291

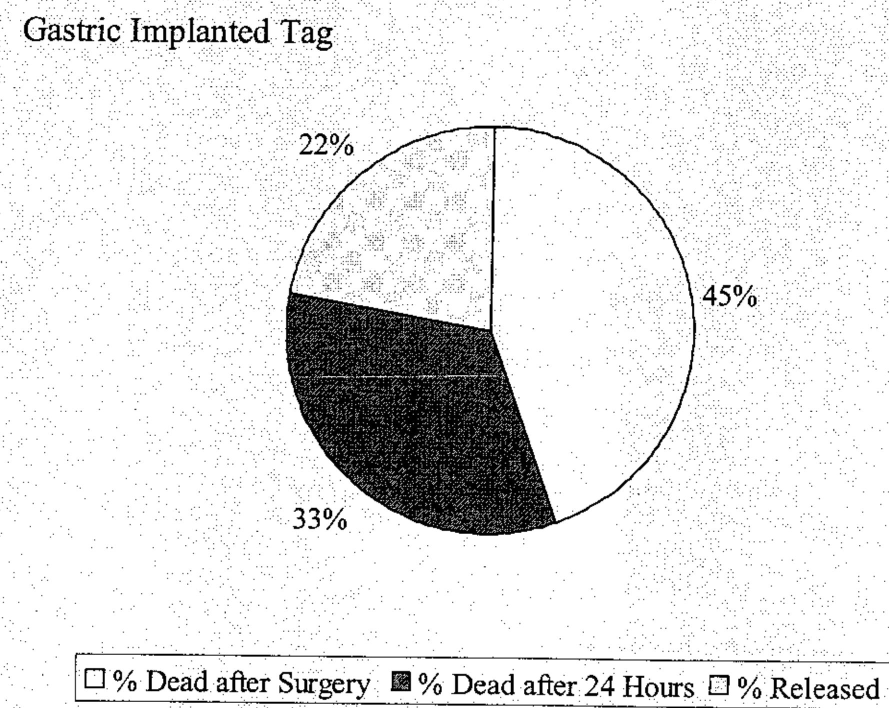
Figure 6. The tagging mortality of (A) fall chinook compared to that of (B) steelhead during the 2000 field season.





C29292

Figure 7. The differences in mortality from (A) gastric implanted tags and (B) surgically implanted tags.



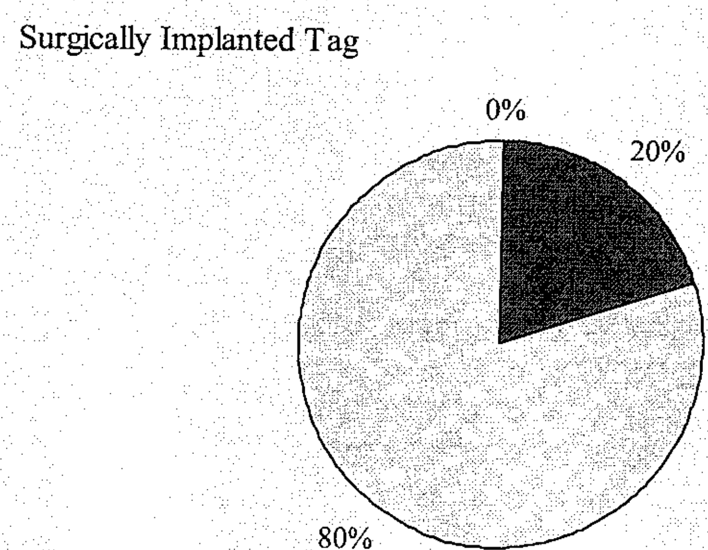
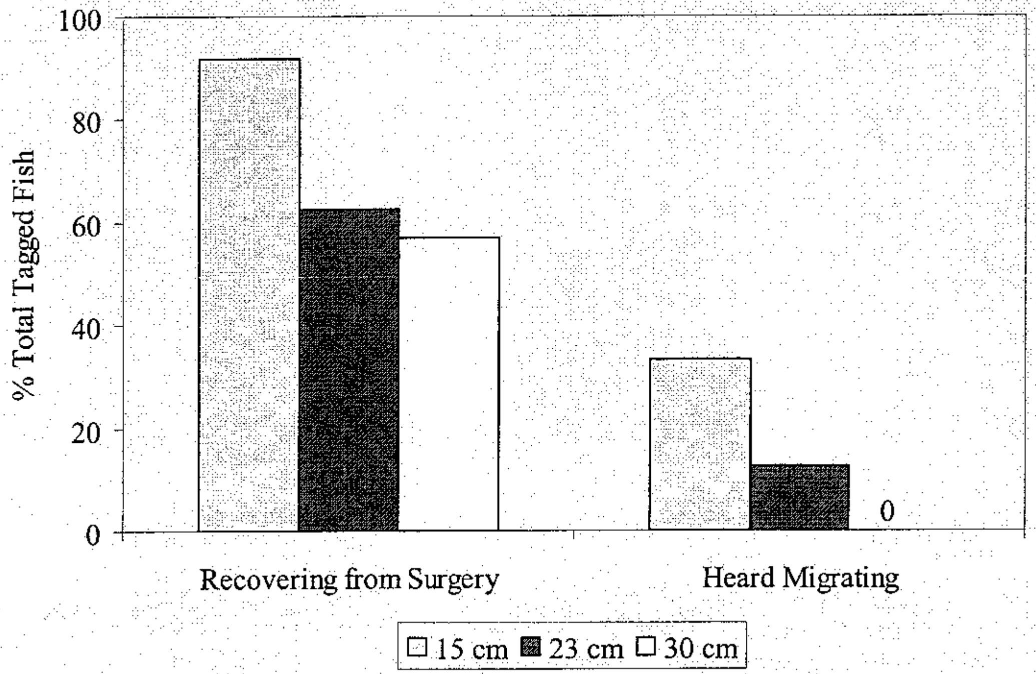


Figure 8. The effect antenna size had on the percentage of fish recovering from surgery and those heard migrating.



C29294

Figure 9. All data collected in the estuary for (A) barged and ROR fish combined, (B) barged fish, and (C) ROR fish; dots represent data collected by aircraft and lines are data obtained by boat tracking.

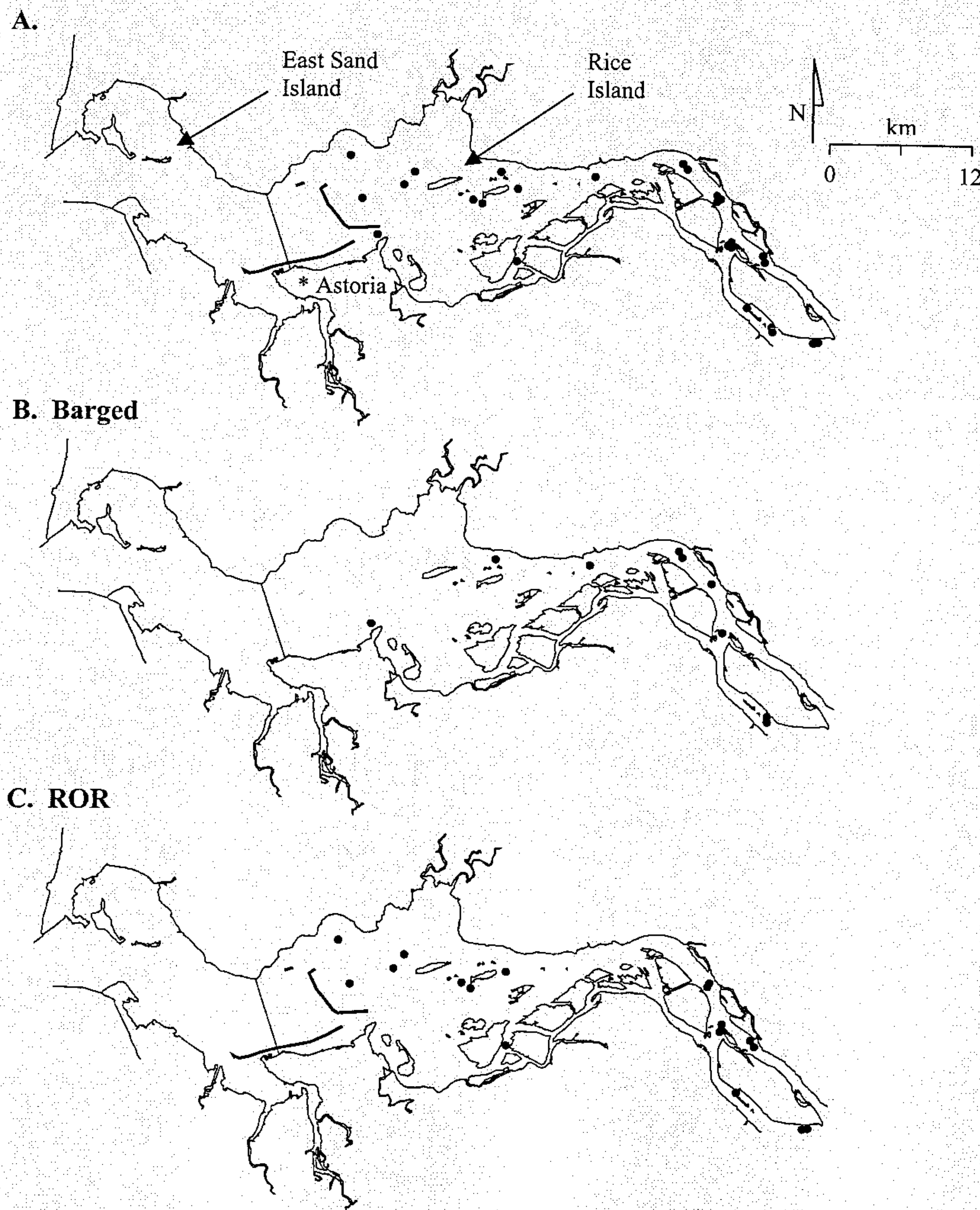
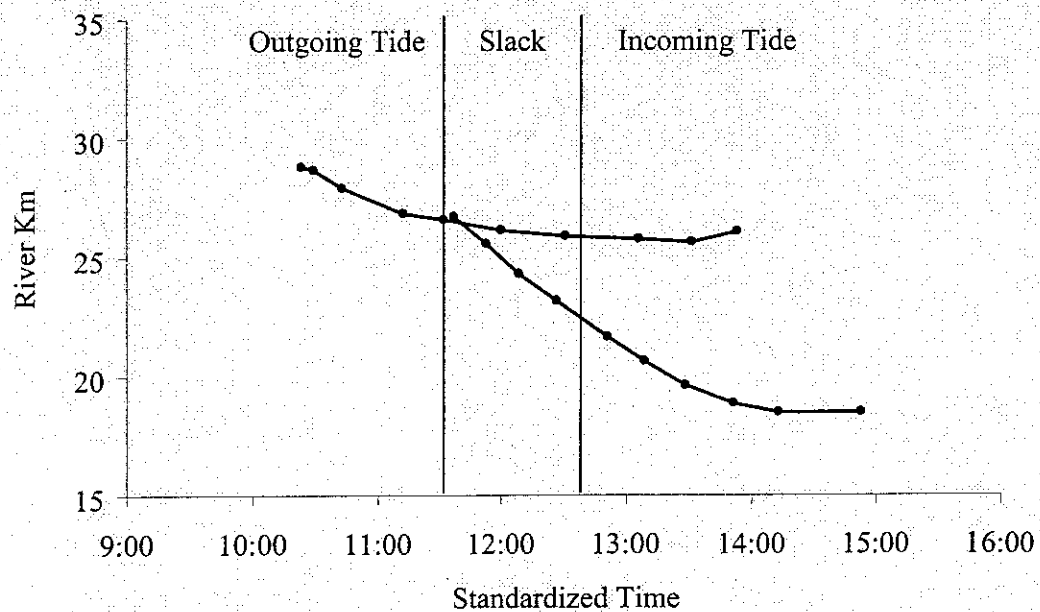
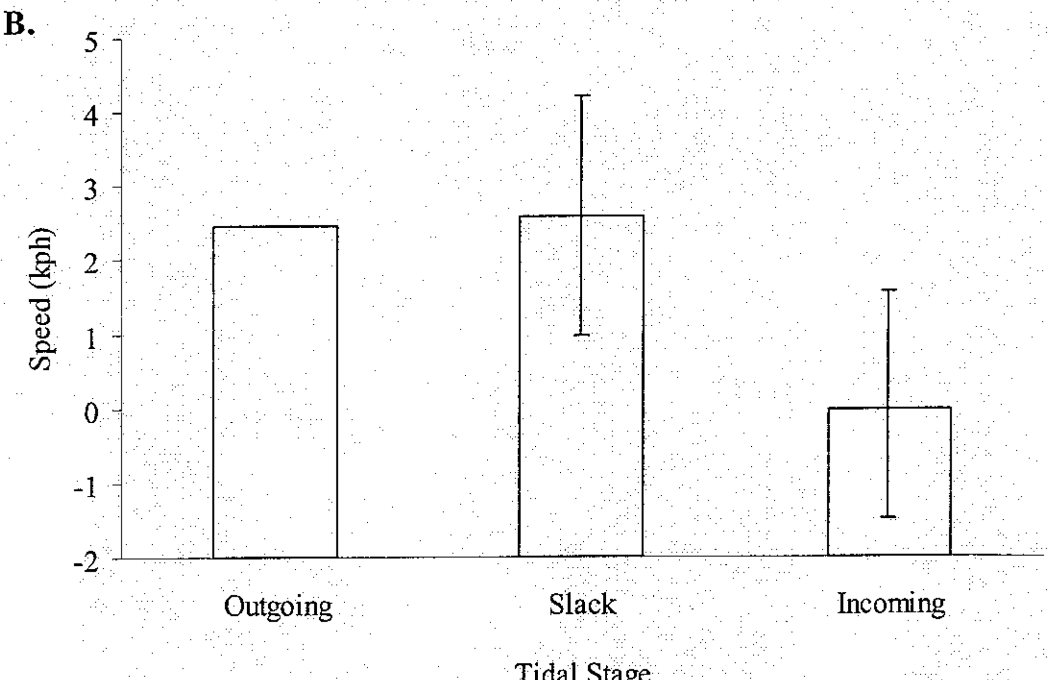


Figure 10. (A) Migration speed in relation to tide of two fish tracked by boat in the estuary. (B) Average speed of all tracked fish in the estuary during different tidal stages, error bars show the range of speeds. Significant differences are described in the results section.

A.

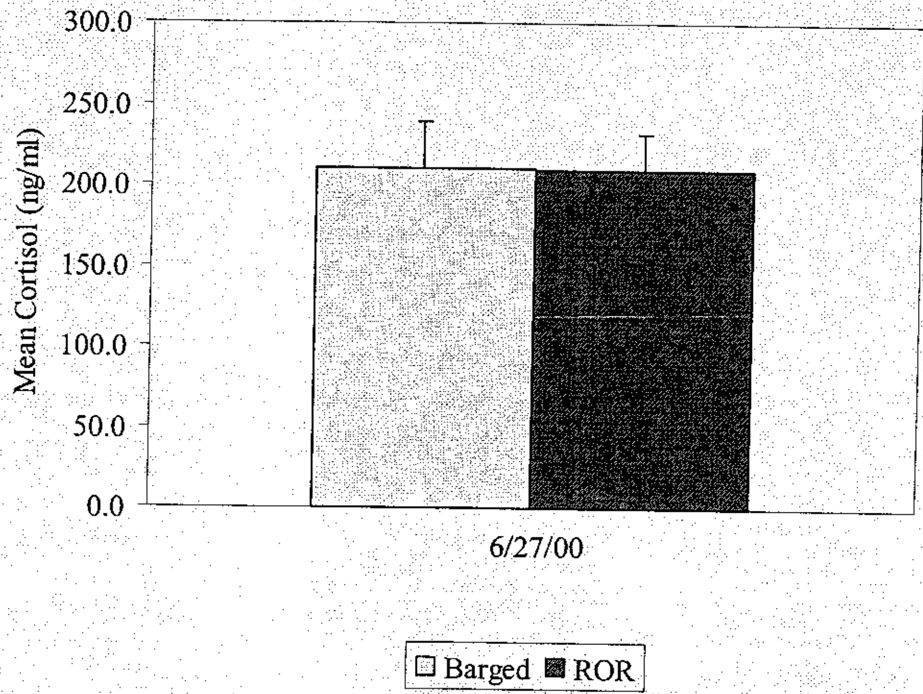


B.

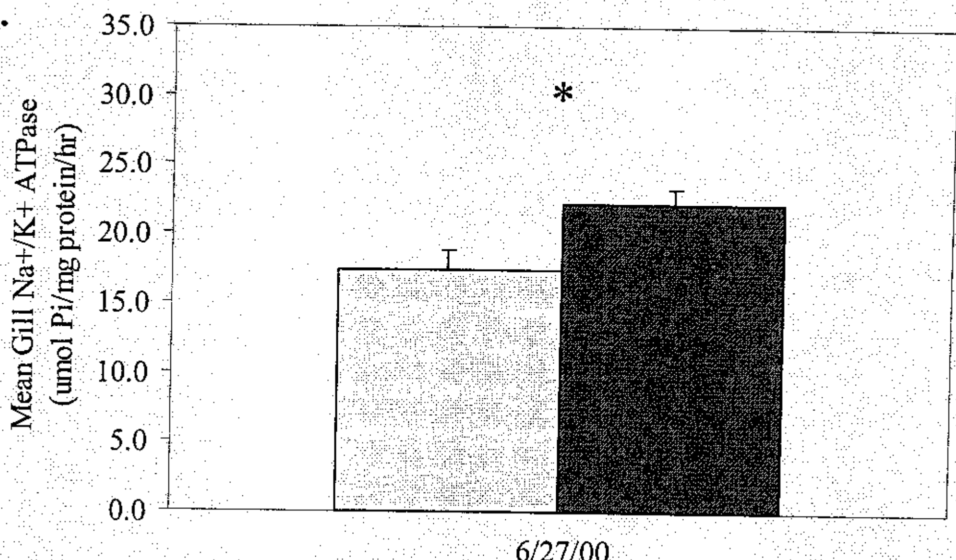


C29296

Figure 11. (A) Mean plasma cortisol (+ SE) levels and (B) mean gill Na^+/K^+ ATPase (+ SE) of barged and ROR fall chinook. Significant differences between types are indicated by asterisks (*).



B.



C29297

Figure 12. The percent of barged and ROR fall chinook infected with certain levels of Bacterial Kidney Disease (BKD) in the physiological sampling (n=10 for each). Significant differences are described in the *Results* section.

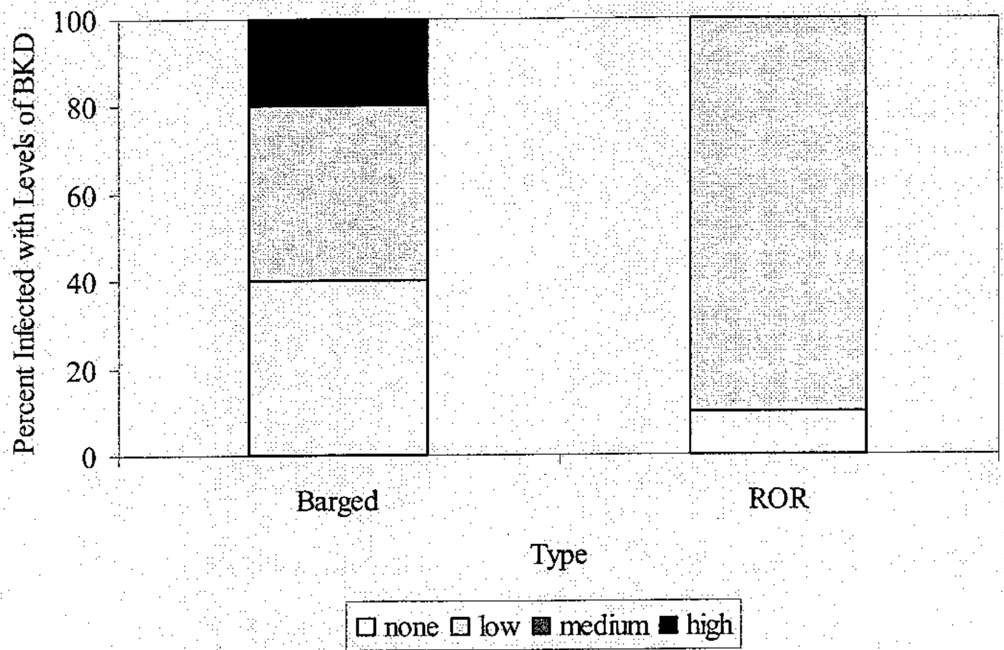
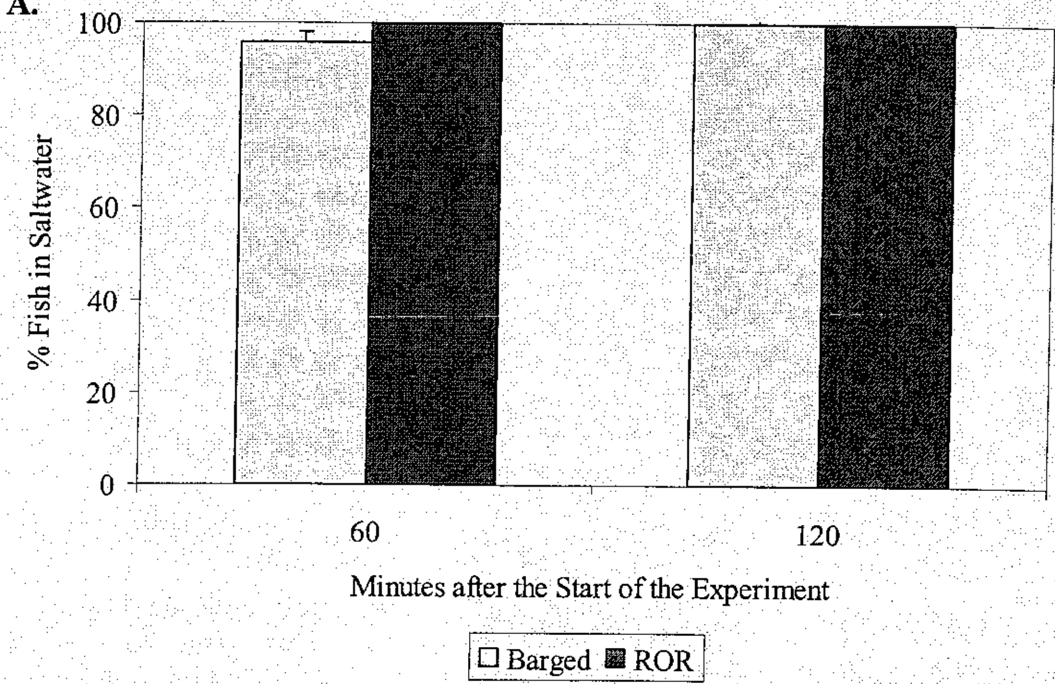
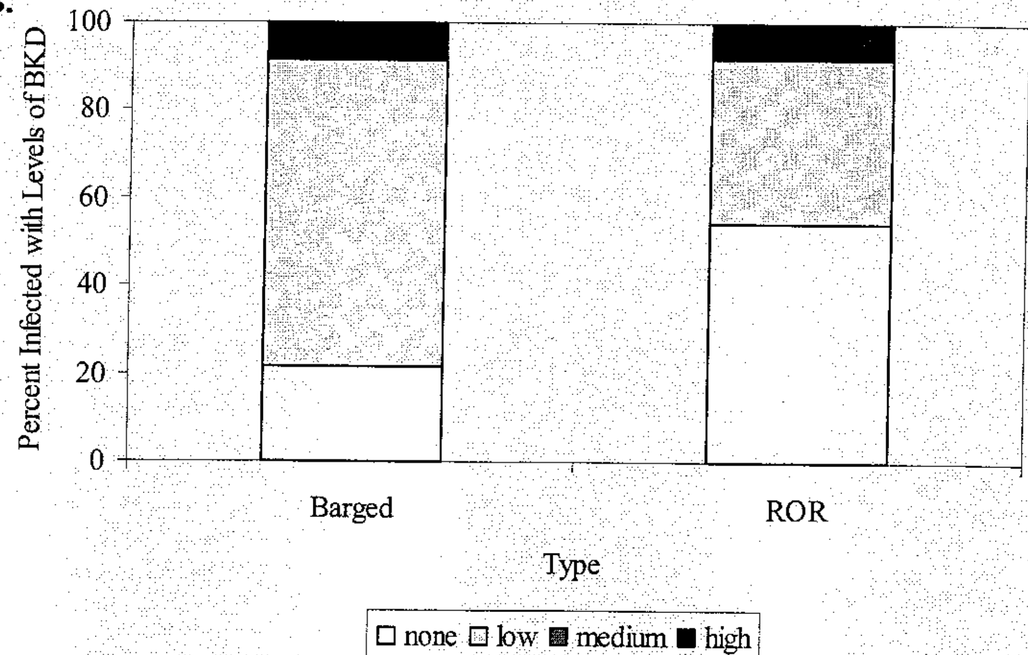


Figure 13. (A) The percent of fish in saltwater 60 minutes after the start of the saltwater preference experiment and those in saltwater after 120 minutes. Error bars indicate the SE between replicate tanks (only on barged fish at 60 minutes, 0.04). (B) The percent of fish infected with certain levels of BKD in this experiment. Significant differences are described in the *Results* section.

A.



B.



C29299